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A DEP Chip with Arc-Shape Microelectrode Arrays for the Separation of Different-size Particles

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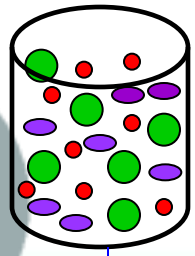
Outline

- Motivation
- DEP Theory
- Simulation
- Chip Fabrication
- Experimental Setup
- Experimental Results and Discussion
- Conclusions

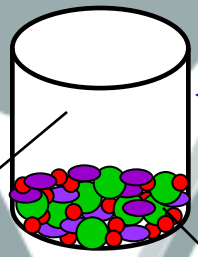
Motivation



Human Urine Sample

by centrifuge

Grade Examination of Bladder Cancer Cells



a clear supernatant liquid

Urine sediments ⟹ (Such as: Red blood cell, epithelium cell…etc.)

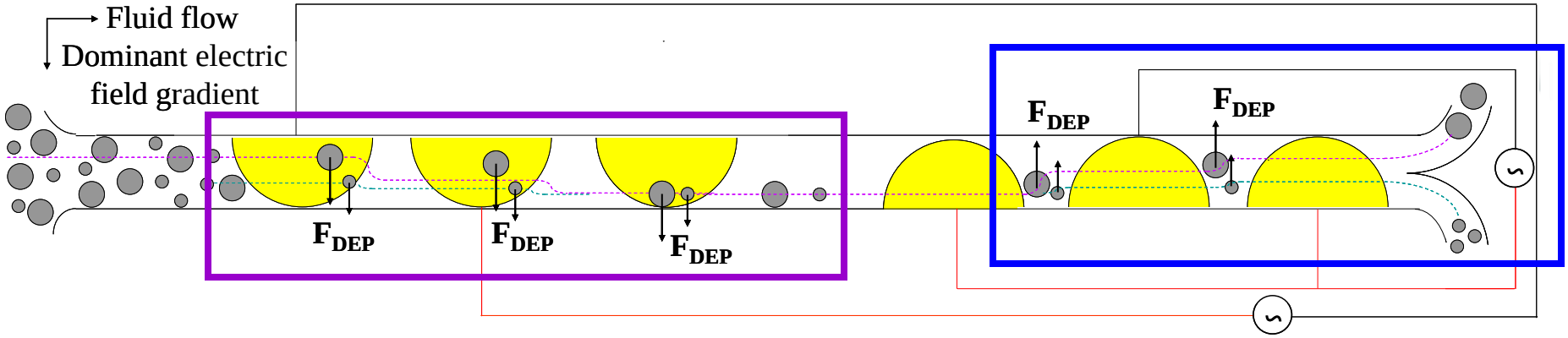
DEP Chip for Particles Separation

Red Blood Cell about 8 μm

Bladder Cancer Cells about 16 μm

Impedance Sensing of Bladder Cancer Cells Based on a Single-Cell-Based DEP Chip

Motivation
-Mechanism



Part I. – Particles Align
Applied voltage : 50V_{pp}
Frequency : 50KHz

Part II. – Particles Separation
Applied voltage : 10V_{pp}
Frequency : 50KHz

DEP Theory

$$\mathbf{F}_{DEP} = 2\pi\varepsilon_m R_P^3 \,\mathrm{Re}[f_{cm}(\omega)]\nabla E^2 \quad (1)$$

$$f_{cm}(\omega) = \frac{\varepsilon_p^* - \varepsilon_m^*}{\varepsilon_p^* + 2\varepsilon_m^*} \quad (2)$$

$$\varepsilon^* = \varepsilon - j\frac{\sigma}{\omega} \quad (3)$$

F_{DEP} = DEP Force
ε_m = Permittivity of Medium
R_p = Particle Radius
∇E^2 = Gradient of the Electric Field of Square
f_{cm} = Clausius-Mossotti

ε^* = Complex Permittivity
P = Particle
m = Medium

ε= Permittivity
σ= Conductivity
ω= Angle Frequency

DEP Theory

$$\mathbf{V}_{Total} = \mathbf{V}_{DEP} + \mathbf{V}_{Hyd} \quad (4)$$

V_{DEP} = Dielectrophoretic Velocity
V_{Hyd} = Hydrodynamic Velocity

$$F_{DEP} = -F_{Drag} = 6\pi\eta R_P \mathbf{V}_{DEP} \quad (5)$$

F_{Drag} = Drag Force Velocity
η = Liquid Viscosity Dynamic

$$\mathbf{V}_{DEP} = \frac{\varepsilon_m \,\mathrm{Re}[K(\omega)]}{3\eta} R_P^2 \nabla E^2 \quad (6)$$

$$V_{DEP} \propto R_P^2 \nabla E^2 \quad (7)$$

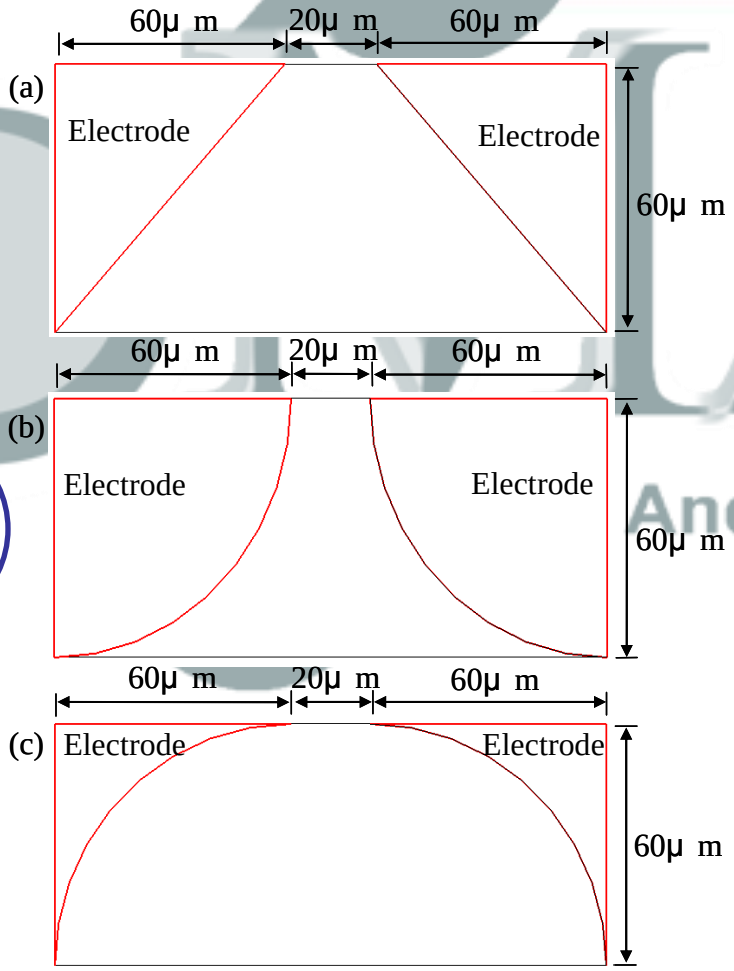
Simulation

-Electrode Model

Trapezoid Electrode

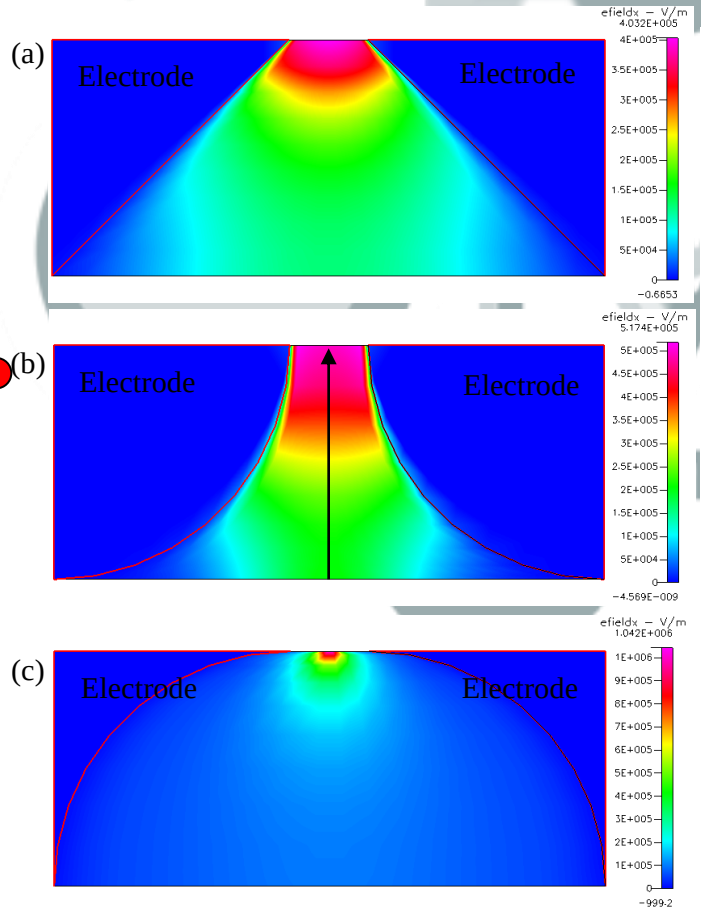
Convex Arc-shape Electrode

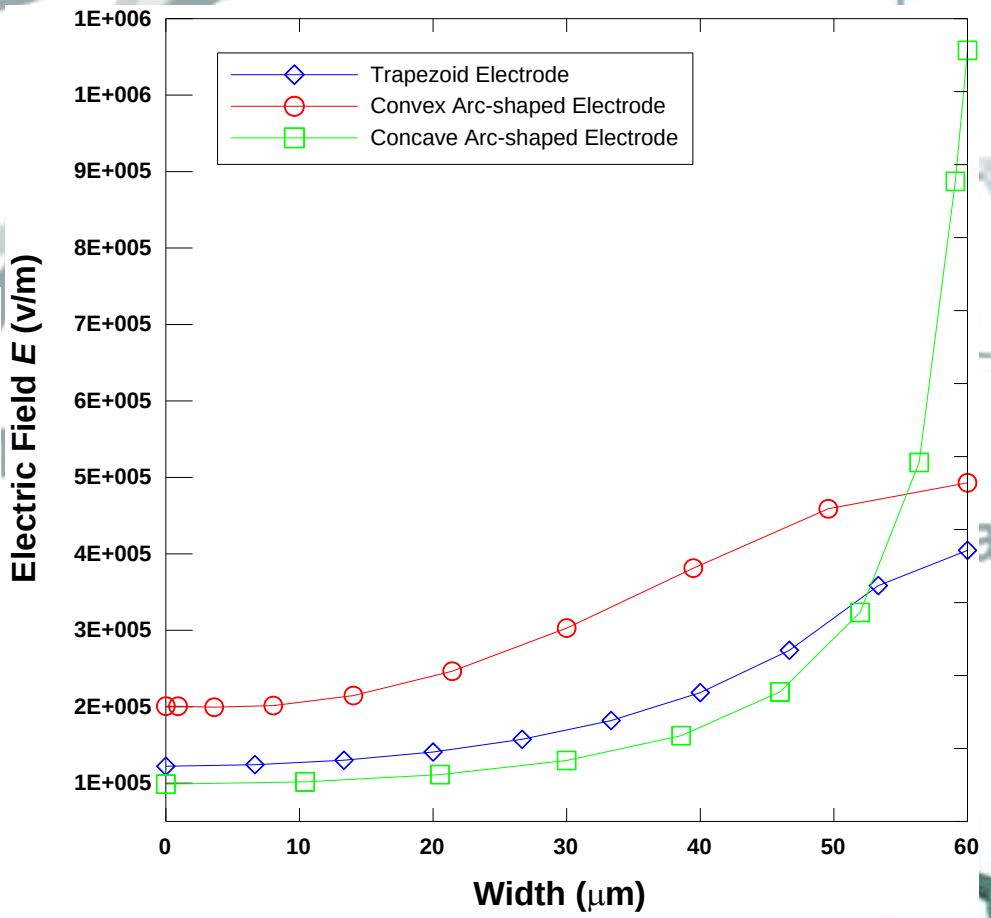
Concave Arc-shape Electrode



Sungyoung Choi, ”Microfluidic system for dielectrophoretic separation based on a trapezoidal electrode array”, Lab on a chip, 2005

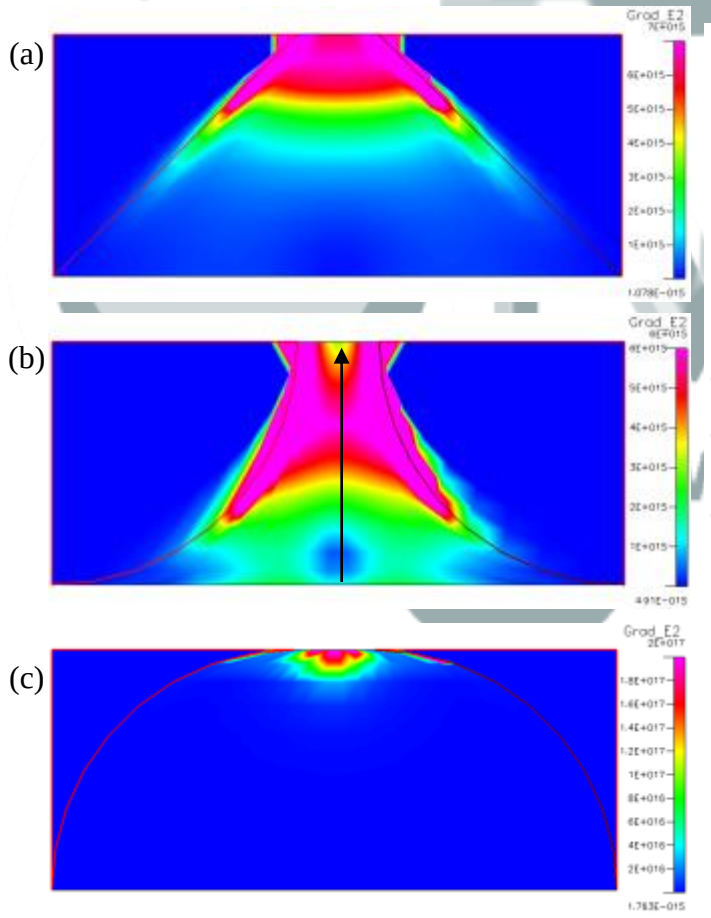
Simulation
-Electric Field

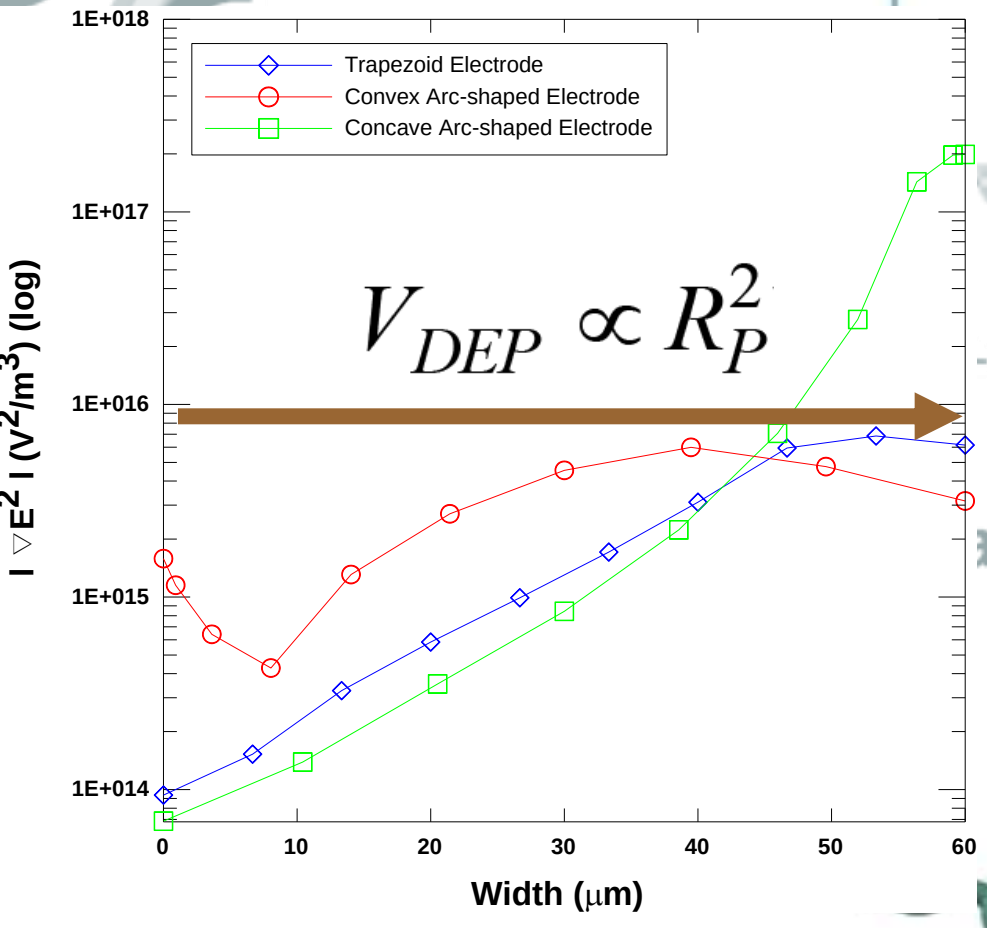




Simulation

- Gradient of Electric Field of Square



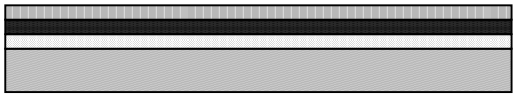


Chip Fabrication

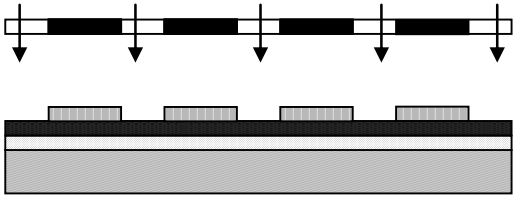
a. Convex Arc-shapes Electrode

Deposit Cr/Au Electrode Layer

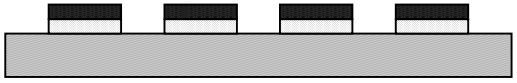
Coat PR 1813



Expose → Develop



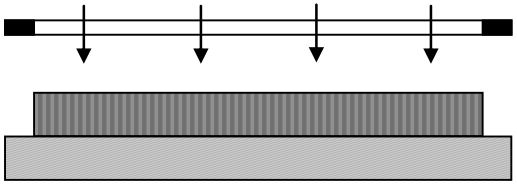
Hard Bake → Remove PR 1813



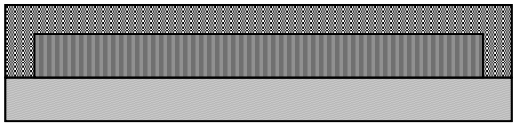
b. PDMS Flow Chamber

Coat SU-8 Layer

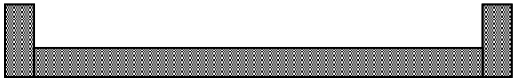
Soft Bake → Expose → Post Expose Bake → Develop → Hard Bake



PDMS Molding

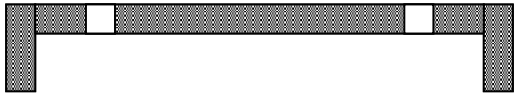


PDMS De-molding

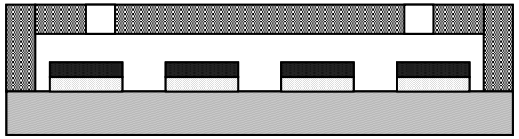


c. Chip Bonding

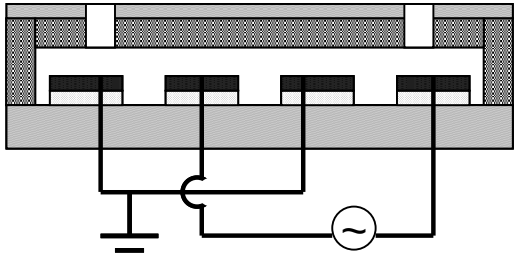
Punch Holes on the PDMS Surface



PDMS Flow Chamber Align Electrode → PDMS and Glass Bonding by O2 Plasma



Drill Holes on the Glass → Glass and PDMS Bonding by O_2 Plasma

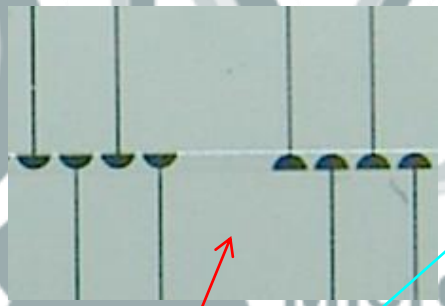


Glass PR 1813 Mask Cr：500Å Au：1000Å SU-8 PDMS AC Signal AC Ground

Experimental Setup

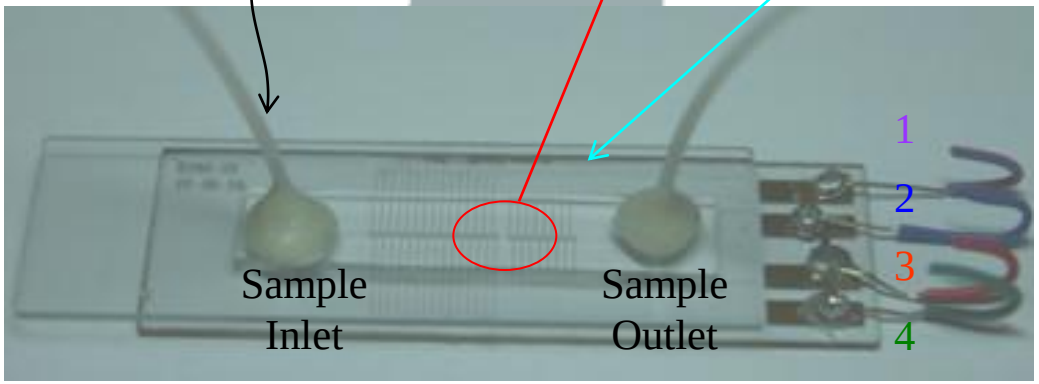
Syringe Pump

Arc-shape
Microelectrode Array



Microscope

Function
Generator



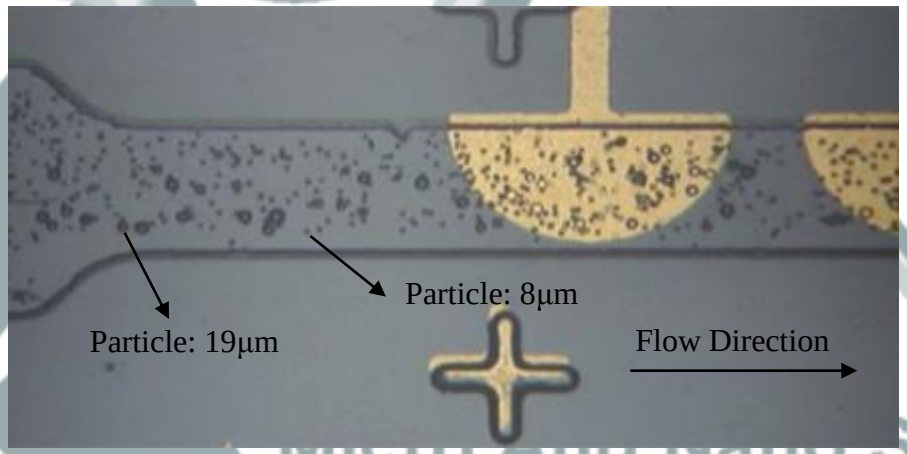
For Separation

For Align

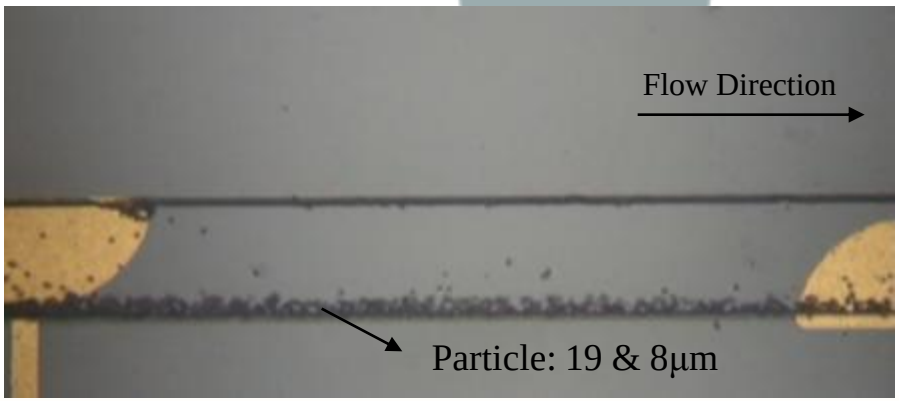
high-frequency amplifier

Experimental Results and Discussion -Particles Align and Separation

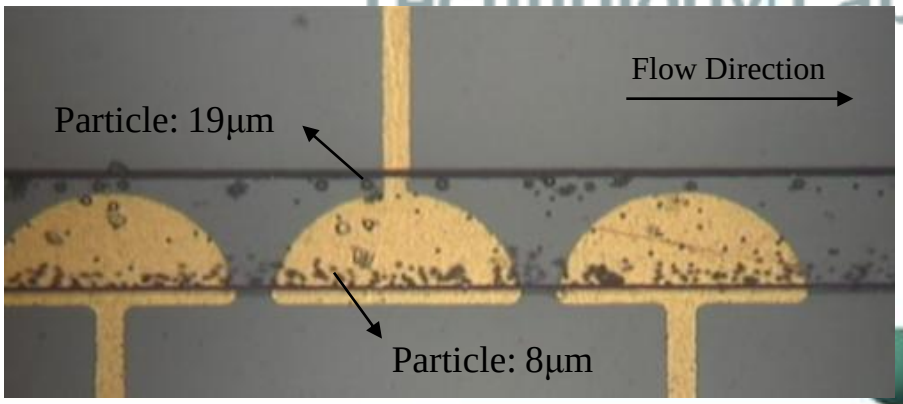
(a). Fulfill the particles of different-size



(b). The **align** of different-size particles



(c). The **separation** of different-size particles



Experimental Results and Discussion
- Cell Manipulation

MCF-10A Cells immersed in sucrose solution (8.63%Wt)

Conclusions

- We have presented the design, simulation, fabrication and measurement of a microfluidic DEP chip with convex-arc shape electrode array (ASEA) for separation of different-size particles.
- The simulation showed a convex arc-shape electrode can provide better separation effect due to the larger effective area of DEP force and relative small variation of ∇E^2 as the applied AC voltage produced a non-uniform electric field within it.
- In part I ASEA, according to the experimental results of the particles align, the N-DEP force was demonstrated by repelling 19μm and 8μm particles to the region of electric field minima after 1 and 5 pairs of convex arc-shape electrodes, respectively, at 50 V_{pp}under 50 KHz.
- In part II ASEA, the experimental results of separation, the particles of 19μm and 8μm can be achieved separation after 5 and 15 pairs of convex arc-shape electrodes, respectively, at 10 V_{pp}, under 50 KHz.
- The MCF-10A cells was pushed by N-DEP force toward to the region of electric field minima after 5 pairs of convex arc-shape microelectrode at 10 V_{pp}, under 1 KHz.

Thank you for your attention!!